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American

POTATO JOURNAL

Volume 36 *May 1959* *Number 5*

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American Potato Journal

PUBLISHED BY
THE POTATO ASSOCIATION OF AMERICA
NEW BRUNSWICK, N. J.

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Entered as second class matter at New Brunswisk, N. J., March 14, 1942 under Act of March 3, 1879. Accepted for mailing at special rate of postage provided for in section 412, Act of February 28, 1925, authorized on March 14, 1928.

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EFFECTS OF SEED-CUTTING DATES ON YIELDS OF VARIOUS POTATO VARIETIES[1]

ROBERT V. AKELEY[2]

Pre-cut seed potatoes have several advantages to northern-State seed growers and also to the tablestock growers in other areas who use them. The tonnage of large tubers shipped to the south for seed is far greater than would be necessary if 2-ounce seed pieces properly cut and suberized were shipped. Small tubers to be planted whole are desirable, but they are usually scarce and high-priced. Freshly cut seed planted in cold soil often rot when weather conditions after planting are adverse, but suberized seed will stand such conditions much better. Surely the best substitute for small whole seed is suberized seed.

Seed growers can utilize their hired as well as their own labor in processing the seed for market throughout most of the storage period well in advance of the actual planting dates. Pre-cut seed could be packaged and shipped in 50- or 100-pound burlap or paper sacks ready for delivery and eventual planting without further processing. The danger of seed piece decay present where freshly cut seed has to be held for some time when weather and soil conditions are unfavorable for planting would be reduced. Susceptibility of seed pieces of pre-cut seed to infection by blackleg or other soil-borne organisms should not be any greater than that expected if small whole tubers were planted, and the stand obtained should be as good.

Selling seed potatoes as small tubers (B size) to be planted whole or larger tubers to be cut in 2, 3, 4, or more pieces would no longer be necessary. Seed growers could use most of their crop for the seed purpose for which it was grown. They would not have to sell a high percentage of over-sized tubers for table stock. Also, seed growers with seed free from ring rot infection would have a better chance of keeping it free from contamination since they would not have to enter into table stock marketing. Therefore, the chances of picking up ring rot infection from commercial equipment, storage houses, and starch factories would be avoided.

When a seed potato is properly cut and the seed pieces are suberized and stored it is of economic importance to determine whether the seed pieces are as valuable for planting as small whole tubers or freshly cut seed pieces of equal size. The experiments discussed herein were designed to compare these factors over different storage periods.

METHODS AND MATERIALS

The data reported here were obtained from yield tests in 1955 and 1956 in Maine and in 1956 in Wisconsin, Connecticut, New Hampshire, and South Carolina. In 1955 tubers of Irish Cobbler, Kennebec, and Katahdin were harvested into bushel boxes at Aroostook Farm, Presque Isle, Maine, and placed in farm storage during the winter at temperatures

[1] Accepted for publication September 5, 1958.

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of 36° to 40° F. At certain intervals bushel lots of each variety were taken from the storage room, cut into seed pieces 1.5 to 2 ounces in size and returned to the storage room. The seed-cutting dates were February 21, March 21, April 20, and May 20. On the last date, May 20, freshly cut seed of all varieties and seed pre-cut on the other 3 dates were planted at Aroostook Farm. The experimental design was a randomized split-block with 6 replications. A single plot consisted of 30 plants spaced 10 inches apart within the row and 34 inches between the rows. Fertilizer of 10-15-15 analysis containing 2 per cent magnesium was applied in bands at planting time at the rate of approximately 1,100 pounds per acre. The usual methods for the area were used for cultivating and control of late blight and insects. On September 9 a killing frost occurred. The potato tubers were then harvested and graded to U.S. No. 1 size and weighed.

With a few exceptions the procedure in 1956 was the same as that used in 1955. Foundation seed of 8 varieties was increased in 1955 on Aroostook Farm. The vines were killed August 26 with an arsenical spray. The tubers were harvested September 9 and 10 and before storage were immersed in an instant dip of a standard solution of Orthocide (5 pounds of 50 per cent captan in 100 gallons). On September 10 and at monthly intervals thereafter, 2 bushels of each variety were cut. After temperatures had dropped below 40° F. in the storage room the whole-tuber lots stored in bushel boxes were brought out into the work-room and warmed up (50° to 60° F.) for 2 days. All tuber samples were cut on the day of removal from storage and the seed pieces were covered with moist burlap sacks for another day so that they would partially suberize before they were returned to the storage room. In the 1956 experiments in each area, the seed pieces of each lot were planted in 4 replications in a randomized split-block design. The 8 varieties were divided into 2 maturity groups as follows: early (Irish Cobbler, Cherokee, Chippewa, and Pungo) and late (Katahdin, Green Mountain, Sebago, and Kennebec). Samples of all varieties for each cutting date were sent to cooperators prior to their normal planting dates.

Yields and Stands

Maine Tests

The average yield and percentages of U.S. No. 1 tubers of 3 varieties of potato from seed cut on 4 different dates in 1955 are given in table 1. Kennebec with an average of 550 bushels per acre had a significantly higher yield than Katahdin or Irish Cobbler. There were no significant differences in yield from seed cut on different dates and the interaction of cutting dates and varieties was not significant, although 88 days elapsed between seed cuttings on February 21 and May 20. All the stand counts were high. Irish Cobbler seed cut on March 21 was the only lot to show any seed piece mold. The infection was slight, however, and apparently did not affect the yields or the stands from seed cut on that date. Kennebec and Katahdin plants showed approximately one-tenth of 1 per cent blackleg throughout the growing season and Irish Cobbler showed 24 per cent.

The 1956 data in table 2 for the 4 early-maturing varieties, and in table 3 for the 4 late-maturing ones give the yields and the stand per-

TABLE 1.—*Effect of dates of seed cutting on yields per acre and percentages of U. S. No. 1 tubers of 3 varieties of potatoes grown at Presque Isle, Maine, 1955.*

Seed-Cutting Date	Irish Cobbler		Kennebec		Katahdin		Mean	
	U.S. No. 1 Yield		U.S. No. 1 Yield		U.S. No. 1 Yield			
	Bus.	*Per cent*	*Bus.*	*Per cent*	*Bus.*	*Per cent*	*Bus.*	*Per cent*
Feb. 21	496	95	560	97	456	95	504	96
Mar. 21	473	95	541	98	444	97	486	97
Apr. 20	458	93	546	97	468	96	491	95
May 20	518	96	553	97	467	97	513	97
Mean*	486	95	550	97	459	96	498	96

*L.S.D. at 5 per cent level between variety means 22 bushels.

TABLE 2.—*Effect of seed-cutting dates on yields of U.S. No. 1 tubers per acre and the percentage stands of 4 early-maturing varieties of potato grown at Presque Isle, Maine, 1956.*

Seed-Cutting Date	Irish Cobbler		Cherokee		Chippewa		Pungo		Mean	
	U. S. No. 1 Yield	Stand	U. S. No. 1 Yield	Stand	U. S. No. 1 Yield	Stand	U. S. No. 1 Yield	Stand	U. S. No. 1 Yield	Stand
	Bus.	*Per cent*	*Bus.*	*Per cent*	*Bus.*	*Per cent*	*Bus.*	*Per cent*	*Bus.*	*Per cent*
Sept. 10	521	99	654	100	595	99	675	98	611	99
Oct. 10	530	100	655	99	529	99	652	96	591	99
Nov. 10	568	100	608	99	655	97	671	93	625	97
Dec. 10	533	97	642	99	604	97	655	97	608	97
Jan. 10	534	94	629	98	530	93	722	93	629	95
Feb. 10	561	98	619	100	615	95	705	98	625	98
Mar. 10	545	97	656	94	608	98	735	96	636	96
Apr. 10	533	100	642	97	622	96	683	97	620	97
May 11	523	100	667	97	603	97	699	99	623	98
Mean*	539	98	641	98	607	97	688	96	619	97

*L.S.D. at 5 per cent level between variety means 54 bushels.

centages for 9 dates of seed-cutting in Maine. The only significant differences indicated were between variety means for yields.

In table 2, the average yield of the early-maturing Pungo (688 bushels per acre) was significantly greater than the yield of Chippewa (607 bushels) and Irish Cobbler (539 bushels). The Cherokee yield (641 bushels) was significantly higher than that of Irish Cobbler, but not different from that of Pungo or Chippewa.

The late-maturing variety Kennebec (Table 3) yielded 668 bushels per acre, which is significantly greater than the yields of Green Mountain (604 bushels), Katahdin (598 bushels), and Sebago (555 bushels). The yield of Sebago is significantly lower than the yields of the other late varieties.

Differences between cutting dates as indicated by yields and the interactions of cutting dates and varieties were not significant in tests with early- or late-maturing varieties as revealed in tables 2 and 3.

TABLE 3.—*Effect of seed-cutting dates on yields of U.S. No. 1 tubers per acre and the percentage stands of 4 late-maturing varieties of potato grown at Presque Isle, Maine, 1956.*

Seed-Cutting Date	Katahdin		Green Mountain		Sebago		Kennebec		Mean	
	U. S. No. 1 Yield	Stand	U. S. No. 1 Yield	Stand	U. S. No. 1 Yield	Stand	U. S. No. 1 Yield	Stand	U. S. No. 1 Yield	Stand
	Bus.	*Per cent*	*Bus.*	*Per cent*	*Bus.*	*Per cent*	*Bus.*	*Per cent*	*Bus.*	*Per cent*
Sept. 10	573	94	547	98	556	100	629	96	576	97
Oct. 10	557	97	532	98	579	96	670	96	584	97
Nov. 10	556	91	642	95	565	99	681	96	611	95
Dec. 10	548	99	566	96	562	94	692	99	592	96
Jan. 10	630	97	637	97	584	93	645	96	624	96
Feb. 10	560	95	605	95	539	97	696	100	600	97
Mar. 10	662	97	643	98	531	93	708	97	636	96
Apr. 10	627	99	632	92	512	94	600	98	593	96
May 11	667	99	637	97	568	96	688	100	640	98
Mean*	598	96	604	96	555	96	668	98	606	96

*L.S.D. at 5 per cent level between variety means 36 bushels.

TABLE 4.—*Effect of seed-cutting dates on mean yields per acre and percentage stands of 8 potato varieties grown in 4 States in 1956.*

Maturity Class of Variety and Seed-cutting Date	Wisconsin		Connecticut		New Hampshire		South Carolina	
	U. S. No. 1 Yield	Stand	Total Yield	Stand	Total Yield	Stand	Total Yield	Stand
	Bus.	*Per cent*	*Bus.*	*Per cent*	*Bus.*	*Per cent*	*Bus.*	*Per cent*
Early Maturity:								
Sept. 10	407	98	187	100	..	..	..	..
Oct. 10	405	99	177	99	..	..	..	..
Nov. 10	404	100	170	100	718	98	..	..
Dec. 10	389	99	176	100	..	..	..	..
Jan. 10	419	99	177	99	734	99	..	..
Feb. 10	401	99	..	..	..	..	..	..
Mar. 10	415	100	172	99	733	100	..	..
Apr. 10*	374	100	169	100	..	..	..	..
May 10*	392	100	..	..	733	99	..	..
Late Maturity:								
Sept. 10	526	98	377	98	..	..	238	95
Oct. 10	528	99	326	100	..	..	226	95
Nov. 10	547	98	343	99	804	97	237	95
Dec. 10	540	99	348	99	..	..	232	96
Jan. 10	555	99	348	99	802	97	233	96
Feb. 10*	551	99	333	99	..	..	211	92
Mar. 10	555	100	358	100	822	100	..	..
Apr. 10*	528	100	328	99	..	..	..	..
May 10*	529	100	..	..	838	97	..	..

*Date of planting freshly cut seed varied a few days from this date, the variation depending upon the State and soil conditions.

The averages of percentages for stand counts for varieties and dates of seed cutting were high. The differences that occurred would normally be expected and are not considered significant. This statement can also be made for the averages of percentages of U.S. No. 1 tubers per acre.

Cooperative State Tests

Additional information was considered desirable in this study of the effects of seed-cutting dates on yields and stands of potato varieties being conducted in Maine. Therefore, similar samples from the same material used in Maine were sent to other States for testing. Cooperative arrangements were set up, the material was divided, and plantings were made by the following research workers: F. J. Stevenson, Red Dot Research Farm, Rhinelander, Wisconsin; R. H. Mullany, Eastern States Farmers' Exchange, Hazardville, Connecticut; A. E. Rich, Agricultural Experiment Station, Durham, New Hampshire; W. M. Epps, Clemson College Truck Experiment Station, Charleston, South Carolina. Also, K. C. Westover, West Virginia University, Morgantown, West Virginia, planted duplicate lots of the material from Maine, but excessive rainfall in West Virginia during the growing season ruined the field tests for yield comparisons. All stands that were counted before the damage was done were very acceptable.

The results from 4 State trials are summarized in table 4. The yields and stands of the early- and late-maturing varieties in Wisconsin showed no significant differences when compared for dates of seed cutting. All yields were high and the stand counts were almost perfect.

Similar tests in Connecticut showed no significant differences in yields or stands between dates of seed cutting for any date or variety. The early-maturing variety yields were seriously affected by drought starting the latter part of July. Late rains helped the situation, and the late-maturing varieties yielded much better.

In the New Hampshire tests the number of seed cutting dates were reduced from 9 to 4. Again, no significant differences occurred in yields between dates of seed cutting. The stands were all acceptable.

Since seed potatoes in South Carolina are planted in February, only 6 dates of seed cutting of the 4 late-maturing varieties were tested for yield and stand comparisons. A late March frost killed back the plants; therefore, tuber size and yield were considerably reduced. There was a range of 158 days between the first cutting date in September and the last date in February, however, the yields and stands were uniform, except where freshly cut seed was planted on February 15. Most of the reduction in yield and stand for this date was due to the poor performance of the freshly cut seed of Sebago. Yields of Katahdin and Green Mountain from seed pre-cut on 5 dates were equal or slightly superior to those from seed freshly cut on February 15.

Discussion

Westover (2), using potato seedstocks of the Rural variety, cut seed in storage at approximately 15-day intervals from October 17, 1921, to April 24, 1922, when temperature ranged from 38° to 42° F. Repeated tests for 1922-23, 1926-27, 1927-28, and 1928-29 led him to the conclusion that

"'Rural potato seed stock which is cut during the storage period and immediately subjected to general storage conditions may be expected to give poorer stands of weak plants and lower yields than will result from the use of freshly cut sets." Lombard (1) compared Irish Cobbler seed suberized 10 to 50 days before planting with freshly cut seed for 6 years (1924-1929) in Maine and concluded that it was not advisable to use for planting seed which had been cut more than 30 days.

The results of Westover and Lombard do not agree with those obtained in this more recent study. No significant differences in yields or stands between dates of seed cutting occurred in any of the 5 States where the tests were conducted. Seed cut on September 10 and planted approximately 243 days later in Maine, Wisconsin, Connecticut, and New Hampshire was not significantly different in yielding ability from freshly cut seed of the same varieties in these States. In South Carolina 158 days separated the September date of seed cutting from that of the seed freshly cut in February at planting time. The yields and stands obtained were uniform for all dates of seed cutting except February. Freshly cut seed produced yields and stands lower than pre-cut seed mostly because of the poor showing of Sebago for that date of seed cutting.

A similarity between yields of varieties and their pre-cutting dates in the Maine, Wisconsin, and Connecticut tests resulted in a non-significant interaction for these two factors.

Blackleg and other soil- or seed-borne diseases did not appear to be problems in any of the States in 1956 although some of the pre-cut seed-pieces were slightly moldy at planting time.

These tests and observations suggest the feasibility of pre-cutting seed in the seed-growing areas well in advance of actual use and of shipping it to growers in burlap or paper sacks ready for planting.

Also, if temperature controls for proper seed suberization were available in suitable railway cars or truck vans, it is possible that seed potatoes could be cut and loaded at once into these vehicles any time after harvest, suberized in transit and thus arrive at their destination ready for planting.

A word of caution is necessary. The seed pieces used in these tests were planted by hand. Commercial planters have automatic pickers that puncture each seed piece 1 to 3 times. These seed-piece wounds can act as points of entry for soil-borne organisms. This risk of infection should not be any greater than that with small whole seed planted with a modern picker planter, and it should be less than that for freshly cut seed under similar conditions.

Summary

The effects of dates of seed cutting on the yields and stands of 3 potato varieties were tested in 1955 in Maine and of 8 varieties in 1956 in Maine, Wisconsin ,Connecticut, New Hampshire, and South Carolina.

A preliminary test using 3 varieties was conducted in Maine in 1955. Eighty-eight days elapsed between the first and the last date of seed cutting. Differences in yields of seed cut on different dates and the interaction of cutting dates and varieties were not significant.

Similar results were obtained in the 1956 tests which included seed of 8 varieties cut, suberized and stored in Maine prior to planting in 5

States. Differences in yields between dates of seed cutting at monthly intervals were not significant in Maine, Wisconsin, Connecticut, and New Hampshire although 243 days elapsed between the earliest and the latest cutting dates. In South Carolina a difference of 158 days between dates of seed cutting likewise had no effect on yields with the exception of Sebago which produced a lower yield when its seed was freshly cut on February 15.

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POTATO TUBER BRUISE ROTS IN RELATION TO CROP ROTATION IN MAINE 1945-1956[1]

DONALD FOLSOM[2]

INTRODUCTION

Potato tuber bruises, so far as this paper is concerned, are cracks and groups of cracks resulting in the tuber flesh from impacts received during harvesting and other handling of the crop. Bruises, even the worst, may remain free from infection by fungi or bacteria. Other bruises become infected resulting in bruise rot which may vary from a thin zone of discolored flesh adjoining the cracks, to larger lesions in which there is no longer evidence of the original cracks (6). Bruises and bruise rots cause losses through their effect on shrinkage and sales appeal. It has been claimed, as will be detailed below, that bruise rot is caused by organisms present on or in the tuber skin at the time of bruising and that the abundance of certain of these organisms is affected by the type of crop rotation that has been practiced in the field in which the crop was grown. Several dozen Maine fields, which were used for potato growing in one or more years of the period 1945 to 1956 inclusive, furnished soil samples which were tested as to pathogenicity in freshly bruised tubers.

ORIGINAL SELECTION OF FIELDS

In 1945, in connection with a study (2) of Fusarium seed-piece decay on Long Island, New York, H. S. Cunningham requested about 100 soil samples from as many different Maine potato fields. Ninety-one samples were taken from 90 fields. As specified by Cunningham, each sample consisted of a half pint of soil taken from near the tubers of hills in several rows. The fields were situated along about 340 miles of road from southwestern to northeastern Maine. Most of the fields adjoining the main road were sampled. The only ones omitted were those which would have necessitated a dangerous automobile parking just beyond a high point in the road. The 91 samples were tested by Cunningham for capacity to infect seed pieces and results were reported to the author by letter. In 7 instances there was no infection, in 44 cases there was infection from which Fusarium sp. was isolated, in 34 instances there was infection from which organisms other than Fusarium were isolated, and in 6 cases there was infection from which no isolation was made. Most of the seed pieces showed a deep discoloration of the typical Fusarium type although a Fusarium was not always isolated.

CROP HISTORY OF FIELDS

When the 90 fields were sampled in 1945 for Cunningham, inasmuch as it seemed probable that crop records and samplings in subsequent years might be wanted, the location of each field was recorded as to speedometer

[1]Accepted for publication September 15, 1958.
[2]Plant Pathologist, Maine Agricultural Experiment Station, Orono, Maine.

distance and as to permanent landmarks. There were several reasons for thinking that later crop records and samplings might be wanted. [1] Major defects in Green Mountain potato tubers had been found in 1932-33 to be due in part to bruise rots (12, p. 209), transplants from which yielded *Phoma tuberosa, Alternaria solani*, and *Fusarium coeruleum* (5). [2] Bruise rot had been blamed in England on *Fusarium coeruleum* and *Phoma foveata* in the soil of fields in which potatoes were being grown (4, 13). [3] Observations over a period of 25 years had shown a wide range in the type of rotation practiced by potato growers in Maine. [4] It was thought possible that the amount of bruise rot might be correlated with crop history.

In each year from 1946 to 1956 the kind of crop grown on each field was recorded. On the average 43 per cent of the plantings were with potatoes, 17 with small grains; 8 with clover; 22 with hay; and 10 per cent with other crops or fallowing. In brief, as an average these annually inspected fields were subject to a rotation of 2 years of potatoes in every 5 years with the other three years mostly in grass and legume crops.

Meanwhile additional evidence accumulated concerning the possible value of the project. According to Small (14), in England *Fusarium coeruleum* rot depends on bruising; infection is from the soil with longevity in the field not known; the fungus may be introduced on the seed after a long rotation. In P. E. I., Canada, (1, p. 54), *Fusarium sambucinum* f. 6 was found to be soil-borne and to enter the tubers through wounds; in some fields the pathogen may be present in abundance, resulting in heavy infection, and, in others, so scarce that mechanically injured tubers do not become diseased; Katahdin is relatively immune, while Green Mountain is highly susceptible. In England (3) there was usually more *Fusarium coeruleum* in the soil after growing a susceptible variety; wide rotation reduced soil infestation. In Holland (10) *Fusarium coeruleum* infects tubers through handling injuries; some soils appear to be heavily infested.

Experiment 1

At harvest-time in 1946, unwashed tubers of three varieties, grown on Highmoor Farm in southwestern Maine, were bagged, 25 medium-sized tubers to a bag, 4 bagsful to a variety. Two bags of each variety were bruised by being dropped from a height of 4 feet to a concrete floor 5 times — on each of four sides and at one end of the bagful. A bruised and an unbruised bagful of each variety were stored at 36° F., and another bruised and unbruised bagful of each variety were stored at 50° F., throughout the winter. Bruising increased the prevalence of lesions. In bruised lots, the higher temperature reduced the number of lesions, and at both temperatures lesions were most abundant in Green Mountains and least abundant in Katahdins. Transplants to potato dextrose agar plates from lesions yielded *Phoma tuberosa* but no other pathogen. Since Cunningham and Reinking (2) found that infection readily occurred at 35 to 40° F. where the tubers were bruised and were inoculated with Fusarium spore suspensions, smears from tube cultures, or infested soil, it seems reasonable to conclude that *Phoma tuberosa*, but no pathogenic Fusarium species, was present on the tubers used in Experiment 1.

Experiment 2

Katahdins were used for a test at Highmoor Farm, in southwestern Maine, started in October, 1955. This variety was chosen because, according to Schrumpf (11), by 1952 the acreage in Aroostook County, Maine, was 57 per cent for Katahdins, 16 for Green Mountains, 11 for Kennebecs, and 16 per cent for all other varieties combined.

In early October, 1955, 26 soil samples (some being duplicates) were taken from 20 of the annually inspected fields in southwestern and central Maine. The most recent year in which potatoes had been grown varied from 1945 to 1955 in the 20 fields. Each soil sample was taken in the following manner. With a trowel 12 small samples were taken from the top two inches, at points about 50 feet apart in the perimeter of a 150-foot square. These 12 samples were mixed in a pan. From the mixture, a pint paper ice-cream container was filled and all the soil that would not go into the container was discarded.

Katahdin tubers grown on Highmoor Farm were washed thoroughly and used to half fill a cotton bag. Five tubers weighing 8-12 ounces, and 5 weighing 5-6 ounces were put into each bag. Part of a soil sample was wet to make a slurry which was poured on the tubers. The half bagful was rocked back and forth to get a good coating of the slurry on the tubers. The tubers were severely bruised by striking the half bagful on the outside 40 times with a metal rod. The half bagfuls were stored in a barrel for 6 months at 38° F.

After storage, each bruise was cut across to disclose any lesion, since lesions did not always show on the outside. Some bruises had no lesions. Lesions were either obviously or possibly at bruises, the latter being where lesions were large, and were reddish-brown to dark brown. The average number of lesions per tuber was 0.6 for unbruised control lots, these lesions probably having developed at digging bruises. The average number of lesions per tuber was 2.8 for bruised control lots not coated with the soil slurry, and 2.3 for the coated lots. This last comparison indicated that the application of the soil slurry reduced rather than increased the development of bruise rot. Further, in the soil-treated lots there was a correlation between the number of years since potatoes had been grown in the sampled field and the number of lesions per tuber. ($r = +.434$, significant at the 5 per cent level.) In other words, the more recent had been the planting of potatoes in the soil-sampled field, the fewer lesions there were per tuber.

Transplants were made to potato dextrose agar plates from 38 representative lesions. Of these, 63 per cent yielded *Pseudomonas fluorescens* and 18 per cent yielded *Colletotrichum atramentarium*. In this experiment the bruised control lots indicated that the pathogen *Ps. fluorescens* (6, 7) was present on the skin of the washed tubers, entered the bruise cracks, and infected them.

Experiment 3

Because tubers are reported (8, 10, 14) as becoming more susceptible to Fusarium rot as they have been in storage longer, experiment 2 was repeated in April, 1956. Katahdin tubers of the same stock as those used in experiment 2 had been kept at 38° F. The soil samples had been kept at 35° F. The same method of inoculation was used followed by storage

for two months at 38° F. After this storage, most of the lesions consisted of reddish-brown flesh adjoining bruise cracks whereas others were brown to black. The average number of these lesions per tuber was 0.5 for unbruised controls, 2.3 for bruised controls, and 1.4 for soil-coated bruised lots. There was no correlation between the number of lesions per tuber and the number of years since potatoes had been grown in the field that furnished the soil sample.

Transplants were made from 49 lesions. The majority of those from reddish-brown lesions yielded *Ps. fluorescens*; one yielded *Fusarium coeruleum*. Most of those from black to brown lesions yielded *Ps. fluorescens* or *Phoma tuberosa* or both; one yielded *Erwinia* and one *Colletotrichum atramentarium*.

In this experiment the bruised control lots indicated that the pathogens *Ps. fluorescens* and *Phoma tuberosa* were present on the skin of the washed tubers and entered the tubers along bruise cracks.

Experiment 4

The possible location of *Ps. fluorescens* and *Phoma tuberosa* on or in the tuber skin was tested further in August, 1956, at Orono. The same stock of Katahdins used at Highmoor Farm in Experiments 2 and 3 had been in part washed in October, 1955, and stored at Orono at 35° F. Tubers were immersed (or not) for 10 minutes in a disinfectant, washed, bruised, and stored for a month at 35, 50, or 70° F. The disinfectant was Agrimycin, 100 ppm.; Clorox, 0.1 per cent; or Phygon, 0.5 per cent. Lesions were reddish-brown to black, were associated with bruise cracks, were reduced in number by the disinfectants, and yielded *Ps. fluorescens* and *Phoma tuberosa* but no other pathogen. The effect of the disinfectants confirm the idea that the tuber skin harbors these pathogens.

Experiment 5

Tubers of the Orono-stored Katahdins referred to in Experiment 4 were inoculated in August, 1956, inside the tuber, with agar cultures of *Fusarium avenaceum*, *F. coeruleum*, *F. sambucinum* f. 6, and *Phoma tuberosa*, and were stored at 50° F. These inoculations all produced rot.

Experiment 6

In early October, 1956, 36 samples were taken respectively from 36 of the annually inspected fields in northeastern Maine. Of these 36 fields, 26 comprised a series (N) varying from 0 to 11 years in the length of time since any potatoes had been grown on them. Another series (L) was made up of 17 fields varying from 1 to 7 years in the length of time since the last crop other than potatoes. The samples were taken by the same method as in 1955, but after any necessary drying they were mixed thoroughly and all small rocks, pebbles, plant fragments, *etc.* were removed.

The same inoculation procedure was followed as in 1955 (Experiment 2) except for two changes. First, each bag contained 4 tubers in the 8-12 ounce class and 6 tubers in the 5-6 ounce class. Secondly, each tuber was bruised before being bagged, with 8 strokes on each large tuber and 3 on each small one.

The tubers were examined in late April, 1957. In the N series, the number of bruises with rot developed was less with a longer period since the last potato crop; $r = -.203$, with significance at the 5 per cent level requiring $r = -.388$. In the L series, the number of bruises with rot developed was greater with a longer period since the last non-potato crop; $r = +.427$, with significance at the 5 per cent level requiring $r = +.482$. More bruises developed rot (84 per cent) where the soil slurry was not added than where it was added (76 per cent). The rot in most cases (99.5 per cent) was a rather thin reddish-brown to black zone next to a bruise crack. Transplants from reddish-brown shallow bruise rot yielded *Pseudomonas fluorescens* in 88 per cent, and from brown to black shallow bruise rot yielded *Phoma tuberosa* in 89 per cent and *Ps. fluorescens* in 67 per cent. Larger brown to black lesions, apparently advancing, comprised 0.5 per cent of all bruise rot and yielded *Phoma tuberosa, Ps. fluorescens,* or *Fusarium avenaceum.*

Experiment 7

In early October, 1956, new Katahdin tubers of the same stock as those used in Experiment 6 were inoculated by placing agar cultures on freshly exposed flesh. Storage was at 35° F. Rot was produced by *Fusarium coeruleum, F. sambucinum* f. 6, *Phoma tuberosa,* and *Ps. fluorescens.*

Experiment 8

In late October, 1956, Experiment 7 was repeated with the addition of inoculating with each soil sample, and with storage at 50° F. for two months. *F. coeruleum* agar cultures produced lesions 2-8 cm. wide and 3-4 cm. deep, with bluish mycelium in each lesion. *F. sambucinum* agar cultures produced lesions 2-5 cm. wide and 1-4 cm. deep, with brown mycelium in each lesion. *Phoma tuberosa* produced lesions 1-3 cm. wide and 1-2 cm. deep. *Pseudomonas fluorescens* produced no lesions. Of the 72 inoculations with soil samples (in each end of a tuber with each sample), only 2 produced lesions, from which were isolated respectively, cultures of *F. avenaceum* and *F. coeruleum.* In England the presence of a pathogenic Fusarium in the soil was shown by infecting tubers through the introduction of soil beneath the skin (4, 9, 13). It may be concluded that the soil samples used in this Maine experiment were practically free from pathogens.

Experiment 9

Experiment 6 was repeated at Orono in late October with 6-8 ounce tubers of the same Katahdin stock. After two months at 50° F., most of the bruises were infected, with the adjoining flesh reddish-brown, brown, or black. The percentage of infected bruises was not increased by the use of a soil slurry. In lots where the soil slurry was used, variation was not correlated with the number of years since the last potato crop, or with the number of consecutive years including 1956 that potatoes had been grown. Of transplants from lesions to potato dextrose agar, 50 per cent yielded *Ps. fluorescens,* 31 per cent *Phoma tuberosa,* and 13 per cent *Fusarium sambucinum* f. 6.

Experiment 10

In March, 1957, Experiment 8 was repeated on both Katahdins and Kennebecs, and the inoculated tubers were kept for 5 weeks at 35° F. Conspicuous lesions were produced by agar cultures of the 4 pathogens listed for Experiment 8, but not by any soil sample. All tubers were removed to a 50° F. storage. After 3 weeks at 50° F., lesions caused by *Fusarium coeruleum* and *F. sambucinum* f. 6 had enlarged considerably and were apparently still enlarging, some lesions caused by *Phoma tuberosa* had enlarged somewhat, and lesions caused by *Pseudomonas fluorescens* had been corked off preventing further increase in size. Of the 144 inoculations with soil, 3.5 per cent had produced reddish-brown to dark brown lesions yielding *Fusarium avenaceum*, 10.4 per cent had produced reddish-brown to black lesions yielding *Phoma tuberosa*, and 3.5 per cent had produced lesions yielding saprophytic fungi or nothing. The highest percentage of inoculations producing *Phoma* rot was with the soil samples from fields producing potatoes in 1956, and no *Phoma* rot was produced by soil samples from fields free from potatoes since 1951 or before. There was no increase in *Phoma* lesions with an increase in the number of consecutive years, ending in 1956, during which potatoes had been grown in the field.

Some Causes of Potato Tuber Rot in Maine in Recent Years

In 1946, an inspector reported that one bin of potatoes in central Maine was about 10 per cent rotted. Isolations yielded *Fusarium sambucinum* f. 6.

In the 1948 Maine crop, 23 samples of rotted tubers yielded *Alternaria solani* in 7 instances; *Fusarium coeruleum*, in 8; *F. sambucinum* f. 6, in 5; and *Phoma tuberosa* in 1.

In the 1951 crop, considerable *Phoma tuberosa* rot developed in one stock of Kennebecs in a part that was graded and bagged in midwinter and kept in storage until spring.

Irradiated tubers of the 1955 crop were examined for pathogen content of lesions. Maine-grown Katahdins yielded *Pseudomonas fluorescens*, Maine-grown Russet Burbanks yielded *Fusarium coeruleum* and *Phoma tuberosa*, and Idaho-grown Russet Burbanks yielded *F. sambucinum* f. 6.

In addition to the recognized causes of tuber rot, lesions have also yielded *Alternaria tenuis*, *Cephalosporium*, *Monilia*, *Mucor*, *Penicillium*, *Rhizopus nigricans*, and *Trichocladium asperum*, but none of these fungi infected tubers in inoculations like those which produced the rot with the recognized pathogens.

The preceding examples of one or another of several pathogens being isolated from tuber lesions, indicate the need for an extensive survey over several years to determine the relationship of tuber rot to kind of pathogen, bruising, variety, tuber maturity, storage conditions, and the general nature of the growing season. Diagnoses on the basis of naked-eye observations without isolations will not be sufficient.

Summary

Ninety Maine fields which were growing potatoes in 1945 were observed for the following 11 years regarding the kind of crop present.

The average crop rotation was 2 years of potatoes in every 5 years, with the other 3 years mostly in grass and legume crops. At the end of the growing season of 1955, soil samples were taken from 20 fields in which the most recent potato year varied from 1945 to 1955. Katahdin tubers were washed, coated (or not) with soil, bruised, stored at 38° F., and examined for bruise rot. The bruise rot, caused by *Pseudomonas fluorescens,* was decreased by soil inoculation, and became more abundant with the increase in number of years since potatoes. The test was repeated in the following spring, when again soil inoculation decreased bruise rot, which in this instance, was caused chiefly by *Ps. fluorescens* and to some extent, by *Phoma tuberosa.* The idea that these two organisms were present on the skin of the washed tubers and entered the tubers along bruise cracks, was confirmed by a further similar test in which bruise rot was reduced by disinfection before bruising.

At the end of the growing season of 1956, soil samples were taken from one series of 26 fields with the last potato year ranging from 1945 to 1956, and from another series of 17 fields with the last 7 years or less consisting of potato years. The 1955 test was repeated. Practically all the bruise rot was soon static and was caused by *Ps. fluorescens* and *P. tuberosa.* It was decreased by soil inoculation and its abundance was not correlated significantly with crop history. In a duplicate test with the storage temperature at 50° F. instead of 38° F., similar results were obtained except that some bruise rot was caused by *Fusarium sambucinum* f. 6.

Internal tuber inoculations with agar cultures produced active rot with *Fusarium avenaceum* at 50° F., with *F. coeruleum* at 35 to 50° F., with *F. sambucinum* f. 6 at 35 to 50° F., with *Phoma tuberosa* at 35 to 50° F., and with *Pseudomonas fluorescens* at 35° F. but not at 50° F. Internal tuber inoculations with the soil samples of 1956, followed by storage at 50° F., produced practically no rot, but when followed by storage first at 35° and then at 50° F. produced some rot which yielded cultures of *F. avenaceum* and *P. tuberosa.* No *Phoma* rot was produced by soil samples from fields free from potatoes since 1951 or before, and the highest percentage of inoculations producing *Phoma* rot was with the soil samples producing potatoes in 1956.

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STORAGE ROT SUSCEPTIBILITY OF POTATO TUBERS EXPOSED TO IONIZING IRRADIATION.[1]

W. J. HOOKER[2] AND D. T. DUNCAN[3]

The use of ionizing irradiation for sprout inhibition of potatoes has shown some promise in prolonging the storage life of the crop (14). In other trials, incidence of tuber rots has generally been higher where tubers have been irradiated especially at levels of irradiation in excess of 12 kilorep, than in similar samples of tubers which were not irradiated (2) (3) (5).

Normal wound healing in potatoes is generally conceded to be an important factor in reducing natural spread of storage rots in potato tubers. Inhibition of periderm activity in tubers exposed to ionizing irradiation has been reported by Waggoner (16) at levels of 20 and 80 kilorep, and by Brownell *et al* (2) at levels of 2.5 kilorep and above.

MATERIALS AND METHODS

Sebago B size tubers measuring 1½ to 2 inches in diameter were used in all tests. B size tubers had the advantage of being uniform in size and a relatively satisfactory number of tubers (approximately 50 tubers) could be packaged in the small samples for irradiation. Trials were replicated 6 times with a total of approximately 300 tubers irradiated at each level for the cold storage and an equal number for the warm storage. These tubers were irradiated with gamma rays from a Cobalt 60 source at levels up to 500 kilorep on December 12, 1956.[4] One lot was stored at 68-70° F. and a second lot was stored at 34-40° F. The percentage of tubers rotted on various days was determined. This lot of tubers was selected because it was naturally infected with bacterial ring rot (*Corynebacterium sepedonicum* (Spieckermann and Kott.) Skapt. and Burk.). These tubers were not artificially inoculated with rot inciting organisms. Tubers suspected of being rotted or partially rotted were cut at each period of observation.

In the second trial, tubers exposed to ionizing irradiation were later inoculated with rot inciting organisms. Gamma rays from the same Cobalt 60 source were used at levels of 0, 5.0, 15.0, 45.0, and 135.0 kilorep.

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[1]Accepted for publication September 22, 1958.
Journal Paper Number 2320 of the Michigan Agricultural Experiment Station, East Lansing, Michigan. This paper reports research undertaken in cooperation with the Quartermaster Food and Container Institute for the Armed Forces, QM Research and Engineering Command, U. S. Army, and has been assigned number 944 in the series of papers approved for publication. The views or conclusions contained in this report are those of the authors. They are not to be construed as necessarily reflecting the views or endorsement of the Department of Defense.

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[4]The authors are indebted to L. E. Brownell, J. V. Nehemias and K. F. Kuipers of the Fission Products Laboratory, University of Michigan, Ann Arbor, Mich. for cooperation and for the use of irradiation facilities.

Sebago B size tubers were grown at the Michigan State University muck farm, East Lansing, Michigan. These tubers were stored at 39° F. until the day of irradiation. After irradiation, tubers were treated as described below and stored at approximately 68-70° F. for 30 days. At the end of the 30-day storage period, tubers were cut for observation.

Rot of potato tubers in storage is commonly incited by 2 important groups of organisms, namely bacterial soft rot (*Erwinia carotovora* (L. R. Jones) Holland) and *Fusarium* dry rots of tubers. *Fusarium sambucinum* Fuck. form 6 Wr. *Fusarium roseum* Link emend. Snyder and Hansen) was used as a representative of the Fusarium tuber rot inciting organisms. In order to evaluate the influence of irradiation intensity on rot incidence, tubers were inoculated with virulent isolates of either *E. carotovora* or *F. sambucinum.*

Following irradiation, equal numbers of tubers from each irradiation level received one of four treatments: *i.e.*, (1) no treatment (a control which was not wounded or inoculated); (2) a control which was wounded but not inoculated with rot-producing organisms (3) a treatment in which the tubers were wounded and inoculated with *Erwinia carotovora;* and (4) a treatment in which the tubers were wounded and inoculated with spores of *Fusarium sambucinum.*

Inoculation was accomplished using a modification of the method of Ayers and Robinson (1). This consisted of wounding tubers to a depth of 10-12 mm. Two 16 penny nails filed to a very blunt point were mounted 10 mm. apart, and extending from a block of wood 10 to 12 mm. The tuber was rolled over this block during the wounding operation making wounds approximately 10 mm. deep and 2-4 mm. in diameter. Each tuber was wounded in 2 distinct areas making a total of 4 punctures. After wounding, the tubers were immersed in a suspension of either fungous spores or bacterial cells. The tubers were then placed between 2 layers of damp Sphagnum moss in wet strength paper bags and covered with plastic sheeting to maintain a high humidity. These tubers were incubated at approximately 60-70° F. for 30 days. Following inoculation, all tubers were cut and the greatest spread of rot in mm. from the point of inoculation in each tuber was measured. A spread of rot greater than 5 mm. from the center of the inoculation hole was considered evidence of infection by the rot inciting organism and was recorded as such. From these data, the incidence and the spread of rot for each irradiation level were determined.

Bacterial soft rot inoculum (*Erwinia carotovora*) consisted of a 1-5 dilution of a 3 day nutrient-dextrose broth culture. Fresh isolates of *E. carotovora* were obtained from soil by way of carrot slice isolation and tested for pathogenicity on potato tuber tissue. *Fusarium* dry rot inoculum consisted of a spore suspension from a 7 day-old culture of *Fusarium sambucinum*[5] grown on potato-dextrose agar. The spore suspension was standardized at approximately 200,000 spores per ml.

In another series of trials, tuber samples of similar sizes were irradiated as in the previous test. Following irradiation, all tubers were cut longitudinally and wounded on the cut surface with the inoculating

[5]Original cultures of *Fusarium sambucinum* were obtained from Dr. G. W. Ayers, Science Service Laboratory, Charlottetown, P.E.I., Canada.

device previously described. One group was exposed to infection at once. A second group was incubated for 3 days at 70-75° F. before being exposed to infection and the third group was incubated for 9 days. Tubers were exposed to infection by immersing into either clean water (non-inoculated control), a suspension of *E. carotovora* cells, or a suspension of spores of *F. sambucinum*. After incubation, tubers were dipped in the appropriate suspension without additional wounding and then returned to the previously described incubation chamber. Following exposure to infection, all tubers were incubated for 7 days at 70-75° F. in flats lined with damp paper towels and covered with plastic sheeting. At the end of the 7 day period, observations on rot development were made.

Experimental Results

The first group of Sebago tubers was naturally infected with bacterial ring rot. Tubers with typical ring rot symptoms were classed as ring rot-infected, even though it is recognized that visual diagnosis of ring rot is not completely reliable. Incidence of ring rot in rotted tubers stored at 34° F. was approximately similar over the range of irradiation levels. At 68° F. storage, ring rot incidence was somewhat higher than at the low temperature storage, but again there was no clear cut trend toward either increased or decreased incidence of ring rot in the stored tubers. Symptoms of ring rot were marked by severe soft rot which followed high levels of irradiation.

Since the amount of ring rot was relatively constant between treatments and since the amount of rot was negligible, combined data of all rotted tubers are presented (Figures 1A and 1B). Toward the close of the normal storage period, 129 days (April 18, 1957) after irradiation, all tubers were cut. Because of the high storage temperature, sprouting was severe and tubers could not be stored longer. In the nonirradiated controls there was a gradual increase in the number of rotted tubers during the storage period. The amount of rot in the nonirradiated control and in the 12 kilorep treatment was very similar. With each increment in irradiation intensity above 12 kilorep, incidence of rot became progressively greater. Tubers broke down promptly in storage at 68° F. when exposed to 500 kilorep irradiation. Although rot was severe at 200 kilorep, it was considerably less than that at the 500 kilorep level.

A duplicate lot of tubers stored at 33-40° F. (Figure 1B) remained relatively free from rot at the lower irradiation levels and in the non-irradiated controls during the 130 day period of observation. As the time of storage was prolonged, incidence of rot progressively increased. It is probable that this lot of tubers could not have been kept over the one-year period of observation. Storage was very unsatisfactory at 500 kilorep because of the rapid development of rot. Irradiation damage was apparent at the 200 kilorep level. Some damage to storage properties was evident at levels of 32, and 80 kilorep. Storage rot at the 12 kilorep level and in the untreated control was very similar except at the last observation. Isolations from diseased tubers were made at the close of the storage period. Over one-half of the *Fusarium* spp. cultures were either moderately or highly pathogenic when tested on nonirradiated tubers. This would suggest

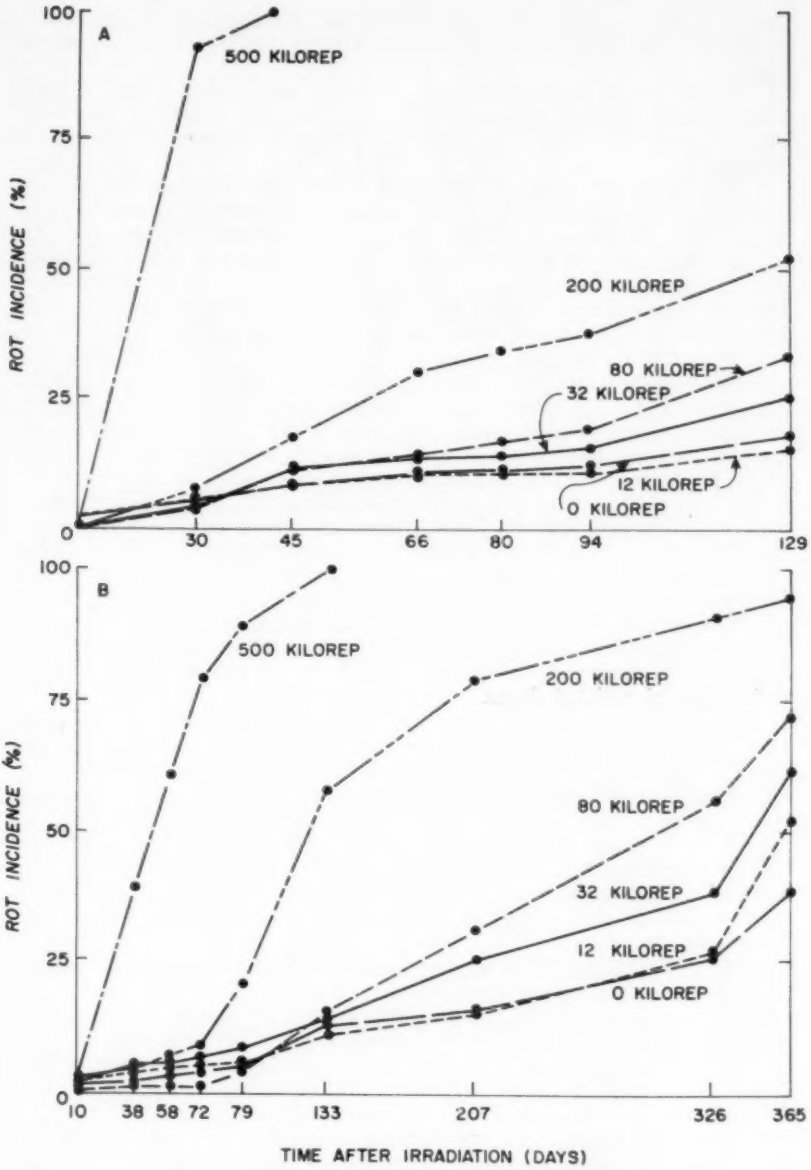

FIGURE 1.—A. Incidence of storage rot in Sebago tubers stored at 68-70° F. following different intensities of ionizing irradiation. B. Storage at 34-40° F.

that storage rots developing even at the close of the storage period necessitated a rather high degree of pathogenicity on the part of the invading fungus.

In the second trial, inoculation of tubers with bacterial soft rot and Fusarium dry rot was completed within 6 hours after irradiation. Rot data obtained at the end of 30 days when stored at room temperature are shown in figure 2.

Rot in the wounded noninoculated tubers was low after the 30 day storage period (Figure 2A) in the nonirradiated control. It was slightly higher at the 5 kilorep level and progressively increased through the 135 kilorep treatment. Rot incidence following inoculation with either organism was considerably higher than in the similarly wounded noninoculated controls. As irradiation intensities were increased, incidence of infection with either Fusarium dry rot or with bacterial soft rot progressively increased.

Spread of rot through the tissue (Figure 2B) was measured from the point of inoculation to the margin of the lesion which had developed in greatest extent in the tuber tissue. The average spread of rot was least in the wounded, noninoculated control treatments. The extent of rot increased slightly as irradiation intensity was increased. Rot in these treatments probably resulted from surface borne organisms introduced into the tissue at the time of wounding. Apparently these organisms were relatively poor invaders. Fusarium dry rot and bacterial soft rot were consistently more aggressive even in the nonirradiated treatments than the average surface borne organisms. The extent of invasion at these irradiation treatments was low suggesting that normal defense reactions in the tuber had been operating at least to some extent. As irradiation intensities were increased the rate of spread through tuber tissue progressively increased. At 135 kilorep the average rate of spread was between 3 and 4 times as rapid as in the nonirradiated tissue.

Infection was established more frequently with Fusarium dry rot than with bacterial soft rot. Fusarium dry rot also spread more rapidly through tuber tissues than did bacterial soft rot. As evidenced by infection and spread in the noninoculated controls, inoculation with pathogenic organisms had a greater effect upon the tuber than did the random assortment of organisms normally present on the tuber surface. The presence of low grade rot inciting organisms on the tuber surface was masked by the more aggressive *E. carotovora* and *F. sambucinum*. The influence of irradiation intensity on infection and spread of rot was similar in all of the 3 wounding treatments.

A third trial was prepared to evaluate the influence of time of wound healing after irradiation on rot incidence and spread. Following irradiation, tubers were slit longitudinally, wounded on the cut surface, and placed in a humid container at 70-75° F. for wound healing. The time interval allowed for wound healing before exposure to rot inciting organisms varied from 6 hours to 9 days. Incidence of rot and rate of spread of rot through tuber tissues was determined after 1 week (Figure 3).

Incidence of rot was low in the noninoculated control which had been wounded within 6 hours following irradiation (Figure 3A). This treatment was comparable to that shown in Figure 1A at the 14-day period. Infection with Fusarium dry rot and bacterial soft rot was high following

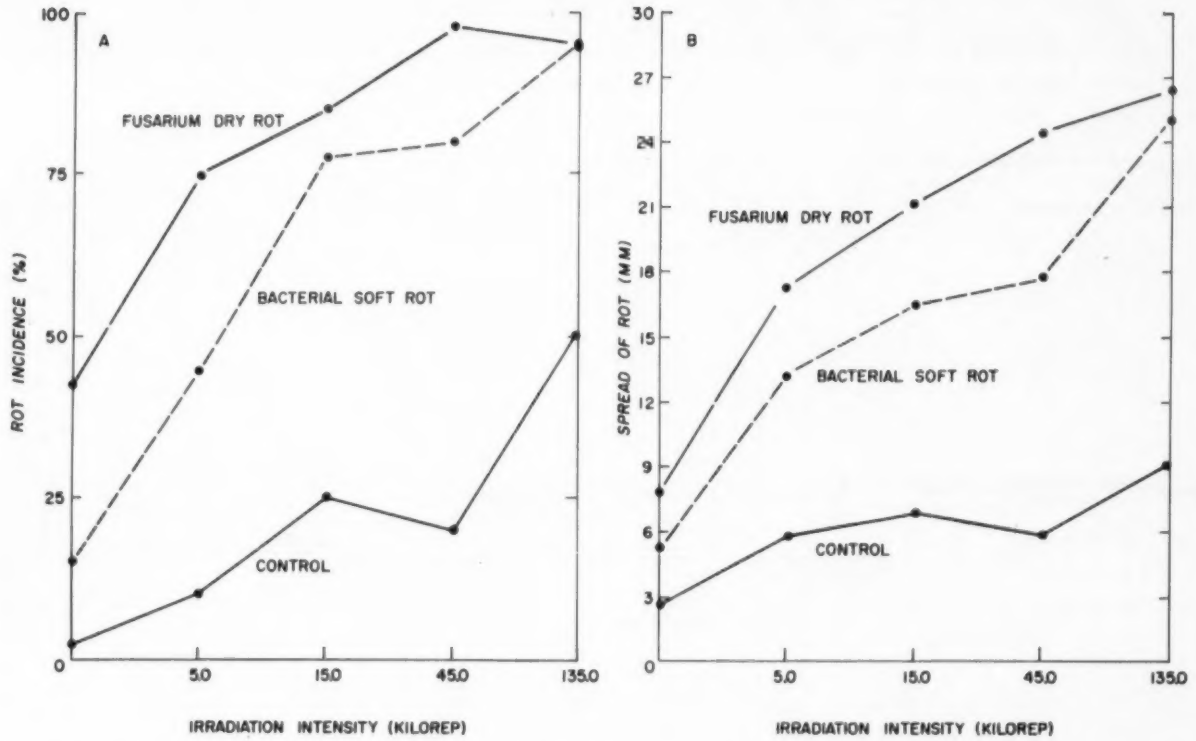

FIGURE 2.—A. Rot incidence in Sebago tubers after 30 days storage at approximately 60-70° F. Tubers were wound-inoculated within 6 hours following ionizing irradiation at 4 levels of intensity. B. Average spread of rot through irradiated Sebago tuber tissue.

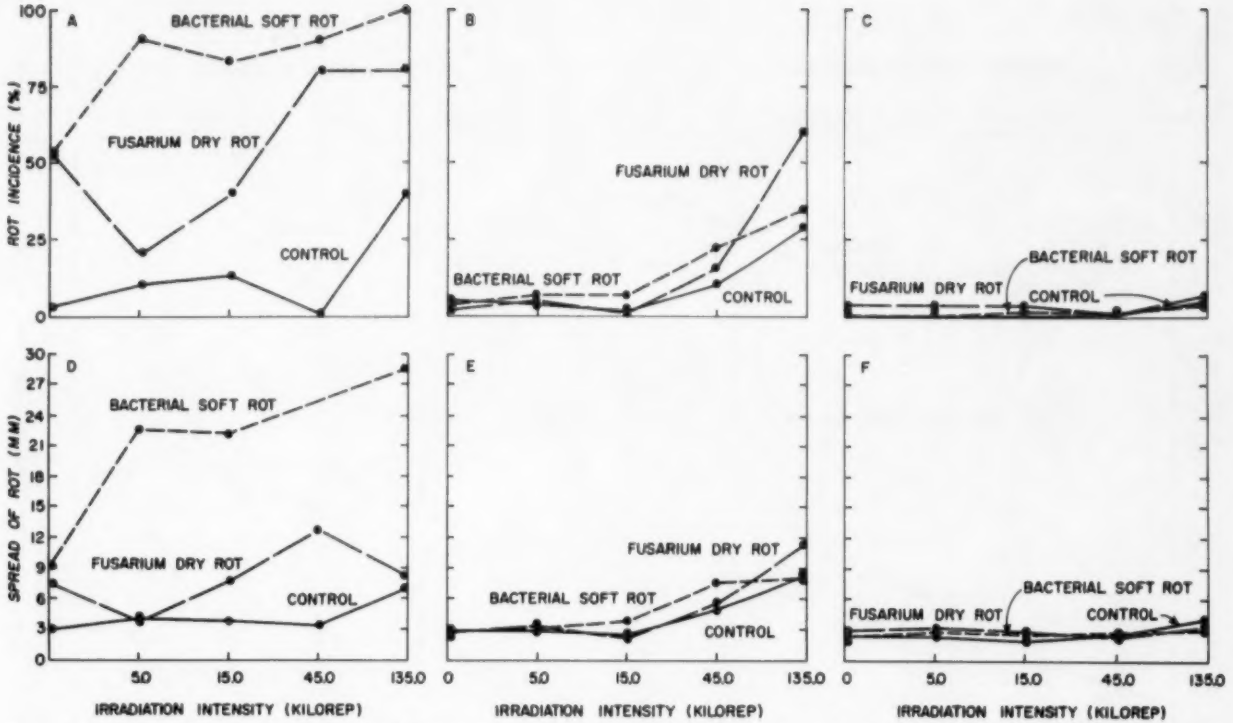

FIGURE 3.—A. Incidence of tuber rot following irradiation, wounding, wound healing for 6 hours, followed by exposure to infection; B. wound healing for 3 days followed by exposure to infection; and C, wound healing for 9 days followed by exposure to infcetion. D, Rate of spread of rot in the tubers described above, wound healing for 6 hours; E, wound healing for 3 days; and F, wound healing for 9 days. After exposure to infection all lots were stored 7 days before examination for rot incidence.

inoculation within 6 hours of time of irradiation. When tubers had been permitted to wound heal either 3 days (Figure 3B) or 9 days (Figure 3C) after irradiation, the incidence of rot was progressively reduced as compared with the 6-hour wound healing period. The increase in rot incidence after 72 hours wound healing (Figure 3B) at 45 and 135 kilorep level suggests that rate of development of natural resistance to rot organisms had been impaired by high levels of irradiation. Apparently the development of natural resistance had been completed after 9 days (Figure 3C) as there was relatively little increase in rot at these irradiation levels.

Rate of spread of rot through tuber tissue following a pattern essentially similar to that of rot incidence, (Figures 3D, E, and F). Factors influencing frequency of infection apparently influenced the rate of spread through tissue in a similar manner. Progression through tuber tissue was most rapid when tubers were inoculated within 6 hours of the time of irradiation. Natural defense mechanisms were apparently effective in retarding the spread of pathogens after 3 days following irradiation at low intensities. At higher levels (45 and 135 kilorep) this defense mechanism was not so effective as that at lower levels of irradiation. After 9 days of wound healing tuber tissue exposed to all levels of irradiation was quite effectively protected from rot infection and the rate of spread of rot in tuber tissue was retarded. This trial was repeated on two other occasions with essentially similar results. In these other trials, the drop in both incidence and rate of spread at the 5 and 15 kilorep level (Figures 1A and 1D) following inoculation with *F. sambucinum* was not obtained. It is probable that tubers responded to Fusarium dry rot in a manner similar to bacterial soft rot.

Discussion

Sparrow and Christensen (14) reported results of potato storage trials following gamma irradiation at levels up to 106 kilorep. They did not indicate in their tests that storage rots were a problem although they stored their potatoes up to 18 months at 5-7° C. Their highest level of irradiation (106.25 kilorep) was somewhat lower than levels in our trials which caused rather severe rot (200 kilorep and above) in the 12-month storage period reported. Appreciable amounts of rot were also obtained at 80 kilorep intensities. The reason for this apparent discrepancy is not immediately clear.

Schreiber and Highlands (12) observed that irradiated tubers had a greater extent of deterioration in storage than did nonirradiated samples. Tuber rots were associated with infection by *Fusarium* spp. and *Phoma tuberosa*. They indicated that rot was the major problem in storage of irradiated tubers. Mukhin and Panasenko (7) observed increased susceptibility of irradiated tubers to *Phytophthora infestans*. They used irradiation intensities of 10, 20, and 100 kilorep.

Gamma irradiation in these trials even at very low intensities, as shown in figure 1, produced changes in the tuber which resulted in a gradual increase in rot incidence over a long storage period. Possibly these changes developed after some time in storage or were somewhat permanent in nature. Waggoner (16), Isleib (6) and Brownell *et al* (2) observed marked reduction in wound periderm development following irradiation.

The inhibitory influence on periderm formation was still evident 67 days after irradiation in the former trial and 50 days in the latter report. Pederson (10) observed an increase in reducing sugars in tuber tissues following exposure to 10 kilorep irradiation. Sereno *et al* (13) observed an increase in total sugars in irradiated tubers as compared with the non-irradiated tubers over a range of storage temperatures (45-60° F.). This difference was most pronounced from the sixth to twelfth month of storage. At 38° F. total sugar concentration in irradiated tubers was higher than that of control tubers throughout the storage period. Roberts and Proctor (11) reported that the middle lamella of tuber tissue was altered resulting in a weakening of the cell wall by irradiation doses of 1000 kilorep and above. Increased susceptibility to tuber rot could well be influenced by any of these changes.

There was also some evidence that other changes in the tuber were temporary in nature. One of these changes caused a delay in recovery from wound injury. When wounding was accomplished within 6 hours (Figure 3) and tubers were exposed to infection at once, rot incidence was considerably higher than when tubers were exposed to infection 3 days or longer after irradiation and wounding. Exceptions to this were at the 45 and 135 kilorep intensities where wound healing processes were apparently not completed until sometime before the 9-day observation. Brownell *et al* (2) observed that suberin formation was delayed from 36 to 48 hours in tubers at 79° F. following irradiation by 15 and 200 kilorep. Within 48 to 192 hours following irradiation, suberization processes had returned to normal. The depth of the layer of suberized cells and intensity of suberization were essentially similar in irradiated and control tubers. Nielsen (8) observed increased susceptibility to soft rot following exposure of tubers to solar irradiation. This was a reversible reaction from which tubers recovered at least to some extent. Nielsen and Todd (9) demonstrated increased cell membrane permeability following sublethal heat treatment. They further demonstrated recovery of cell membrane permeability within 24 hours following certain treatments. Sussman (15) working with 32 kilorep intensities and below observed marked increases in oxygen uptake and in carbon dioxide output in irradiated potato tubers. This effect was marked immediately following irradiation but by the fourth to sixth day after irradiation the rates of oxygen uptake and carbon dioxide output had almost returned to normal. These observations have been confirmed by Gustafson *et al* (4). It is possible that the temporary irradiation injury which delays normal recovery processes in tubers with mechanical injury, is associated with one or more of the latter phenomena.

Summary

1. Sebago tubers were exposed to ionizing irradiation from a Cobalt 60 source and observed for incidence of storage rot.

2. There was no evidence that ionizing irradiation either reduced incidence of rot or enhanced effectiveness of normal defense reactions in the tuber.

3. Incidence of ring rot developing in naturally diseased tubers was not modified by ionizing irradiation except where ring rot symptoms were masked by high incidence of soft rot following severe irradiation injury.

4. Incidence of miscellaneous naturally occurring rots including Fusarium tuber rot and bacterial soft rot in noninoculated tubers was highest in the high levels of irradiation (500 kilorep). Incidence of rot was progressively reduced as irradiation intensity was reduced.

5. Essentially the same trends were obtained in 129 days at 68-70° F. as were obtained in 365 days storage at 34-40° F.

6. The incidence of rot following artificial wound-inoculation with Fusarium dry rot and with bacterial soft rot was considerably higher than incidence of rot in wounded noninoculated tubers.

7. Incidence of rot and rate of spread of rot through tuber tissue were increased at the higher irradiation intensities. This trend was similar in wounded noninoculated controls and in tissue inoculated either with bacterial soft rot or with Fusarium tuber rot.

8. At least some defense reactions in irradiated tubers were operating within 3 days at irradiation intensities of 15 kilorep and below and within 9 days at levels up to 135 kilorep. These reactions were measured over a 7-day storage period at 70-75° F.

9. Ionizing irradiation influenced susceptibility to rot in potato tubers by apparently modifying 2 different reactions. One reaction which was delayed in appearance, especially at low levels of irradiation, was rather permanent from which the tuber did not recover. Rot progressed throughout the storage period at a rate in excess of the nonirradiated controls. The second reaction was apparently temporary from which the tuber recovered within a few days. Irradiated tissue was delayed in normal wound healing processes resulting in a degree of susceptibility greater than that of nonirradiated control tubers at comparable periods of time.

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THE INFLUENCE OF TEMPERATURE ON THE RATE OF ROOT AND SPROUT GROWTH OF POTATOES[1,2]

D. R. ISLEIB AND N. R. THOMPSON[3]

The optimum date to plant potatoes at a given location is not known. Calendar dates do not provide stable criteria for planting because of seasonal variability, although Rich (3) and Akeley *et al.* (1) have found distinct advantages in yield and quality of tubers produced by early planting. According to Hardenburg (2), delayed emergence, increased decay and poor stands result from planting in soil which is too cold. The laboratory experiments reported in this paper were performed in an attempt to define the relationship between temperature and the rate of root and sprout growth of potato pieces.

MATERIALS AND METHODS

All seed used in these experiments had been stored at 40° F. In the initial experiments, twenty-five dormant tubers of each variety to be tested were cut into four seed pieces. These pieces were planted in four flats of vermiculite so that each flat contained one piece from each tuber. Seed pieces from the stem and apical ends of the tubers wer equally distributed among the flats. In the later experiments small tubers were cut in half lengthwise, and distributed at random among the flats. The seed pieces were planted so that each piece was covered with vermiculite to a uniform depth of one inch after watering and subsequent compaction. The flats were watered, allowed to drain, and placed in controlled temperature boxes.

In the preliminary experiment, Sebago seed pieces were inoculated at 45°, 50°, 55°, and 60° F. After 21 days the seed pieces were removed and representative samples photographed to show root and sprout development (Figure 1). In a second experiment, Sebago seed pieces were incubated for 33 days at 46°, 48°, 50°, and 52° F. (Figure2). The flat from the preliminary experiment, incubated at 45° F. for 21 days, was incubated an additional 33 days at 46° F. during this trial. In a third experiment, Onaway (early maturing) and Katahdin (late maturing) seed pieces were incubated 26 days at 46°, 48°, 50° and 52° F. (Figure 3).

On the basis of information from the early studies certain experimental procedures were standardized and more detailed data collected from a later series of trials. Small (about 3 oz.) tubers of ten varieties were split lengthwise and planted with the cut surface down, 25 seed pieces per flat. The vermiculite was autoclaved between trials to control sprout decay during the incubation period. A standard incubation period of 28 days was chosen, and fresh weight of sprouts and roots was determined.

[1]Accepted for publication August 11, 1958.
[2]Journal Article Number 2289, Michigan Agricultural Experiment Station, East Lansing, Mich.
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FIGURE 1.—Sebago seed pieces after incubation at 45°, 50°, 55° and 60°F. for 21 days.

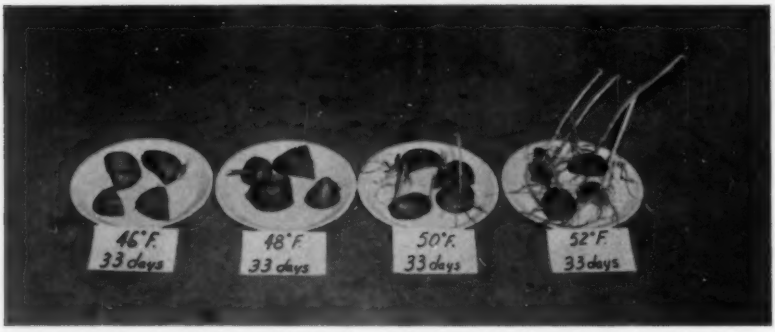


FIGURE 2.—Sebago seed pieces after incubation at 46°, 48°, 50° and 52°F. for 33 days.

RESULTS AND DISCUSSION

In the first experiment no sprouts had emerged at 45° F. At 50° a few sprouts had emerged, and at 55° and 60° emergence and growth were relatively advanced. This suggested a critical temperature for growth in the range of 45-50° F. In the second experiment an attempt was made to narrow the limits which define the critical temperature. Very little sprout emergence was observed at 46 or 48°. Some emergence occurred at 50°, and at 52° emergence and growth were about equivalent to that at the higher temperatures in the first experiment. There was no indication that time was limiting emergence, as the seed pieces held 54 days at 45-46° had grown very little more than those held only half as long at the same temperature. The third experiment indicated that the early variety Onaway grew more rapidly at a given temperature than did the late variety Katahdin. The critical temperature for growth in this trial was close to 48° F.

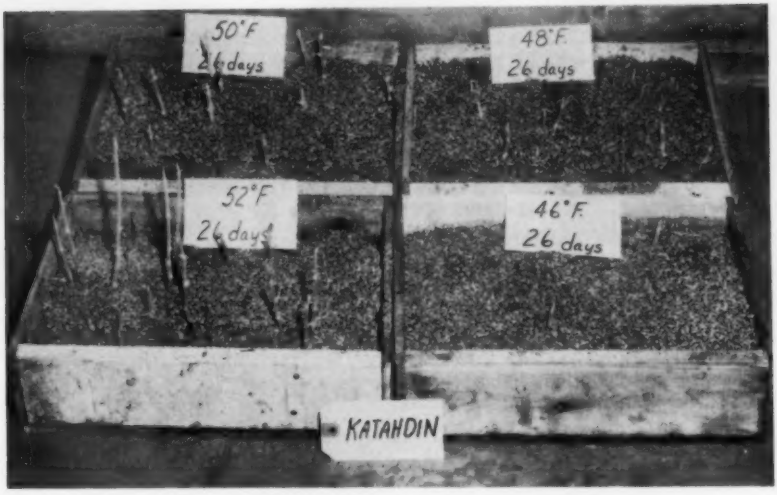
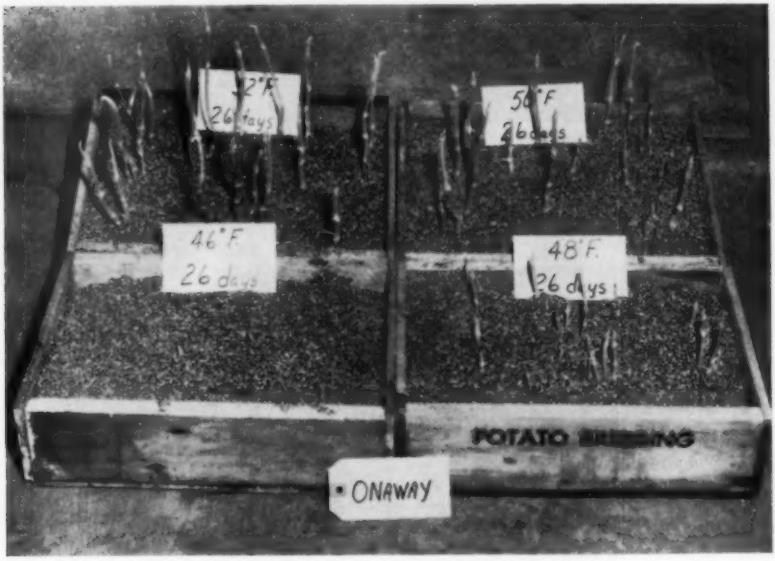


FIGURE 3.—Onaway (below) and Katahdin (above) seed pieces after incubation at 45°, 48°, 50° and 52°F. for 26 days.



These preliminary trials suggested that further study of the sprouting response to temperature would enable more precise planting date criteria to be developed. It also seemed possible that the difference in growth rates between clones might be a useful tool in establishing the maturity group of seedling selections.

Data on root and sprout weight from the ten varieties subsequently tested are shown in table 1. Growth at 46° F. was very slow, averaging 0.2 g. fresh weight of sprouts and 0.02 g. of roots per seed piece. As the temperatures were increased both sprout and root weight increased .The data do not indicate that optimum temperature for growth was within the range used in these experiments.

The data in table 1 show that sprouts and roots of Merrimack, a late variety, grew slowly; that sprouts and roots of Onaway, an early variety, grew rapidly; but Tawa, another early variety, showed slow root growth. There was little difference in the minimum temperature required for growth, but growth at any given temperature may differ markedly between varieties. Thus the critical temperature for growth seems relatively well

TABLE 1.—*Fresh weight of roots and sprouts from 25 seed pieces of ten potato varieties incubated in vermiculite at 46°, 48°, 50° and 52° F. for 28 days.*

Variety		Fresh Weight, Grams				
		46°	48°	50°	52°	Mean
Irish Cobbler	Roots	1.96	3.62	52.82	51.38	27.44
	Sprouts	11.57	35.05	98.76	54.58	49.99
Tawa	Roots	0	9.31	28.38	56.32	26.26
	Sprouts	1.05	9.31	38.38	56.32	26.26
1111-8	Roots	1.00	6.32	27.10	20.02	13.61
	Sprouts	3.29	15.43	46.44	33.82	24.74
Onaway	Roots	0.33	0.51	23.12	33.84	14.45
	Sprouts	5.38	15.77	65.56	83.90	42.65
Delus	Roots	0	0.76	2.09	3.30	1.54
	Sprouts	3.08	14.03	17.13	25.88	15.03
Red La Soda	Roots	0.28	5.56	3.66	14.25	5.94
	Sprouts	5.31	34.82	30.25	52.44	30.70
Russet Rural	Roots	0	0.30	1.85	24.18	6.58
	Sprouts	2.37	17.27	28.43	59.27	26.84
Sebago	Roots	0	0	5.36	19.51	6.22
	Sprouts	3.12	17.40	30.45	72.75	30.93
Merrimack	Roots	0	0.	0.22	3.59	0.95
	Sprouts	0.86	5.65	7.60	18.01	8.03
Saco	Roots	0.31	6.85	2.00	13.83	5.75
	Sprouts	9.33	63.01	49.23	63.39	47.49
Mean	Roots	0.39	2.39	11.94	19.14	8.47
	Sprouts	4.45	22.77	41.22	52.54	30.27

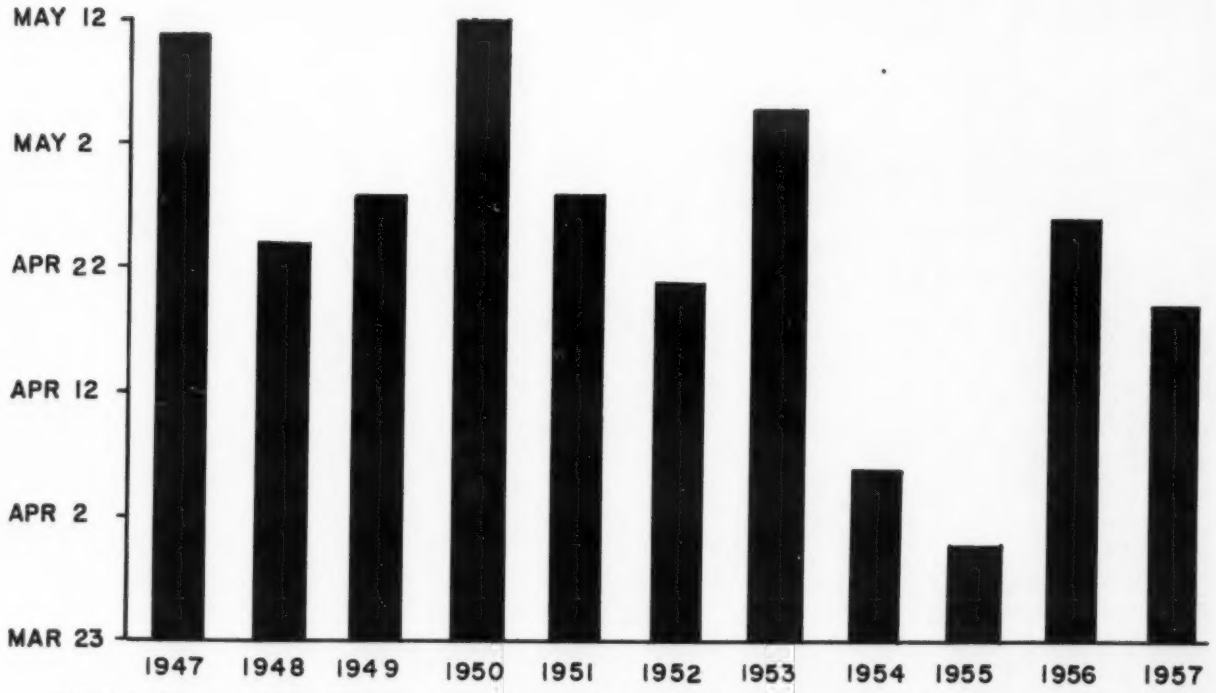


FIGURE 4.—Dates on which soil temperatures, 6" below surface, arrived at and remained above 50°F. East Lansing, 1947-57.

defined in the limits of 48-50° F., but in this range one variety may decidedly out-perform another.

Sprout and root growth of potato seed pieces would not be reliable criteria for predicting seasonal maturity of field-grown potatoes. In some cases, such as Irish Cobbler and Onaway, both sprouts and roots grew faster than the average for the ten varieties, which would seem to confirm the theory of earliness being associated with fast growth. The late variety Merrimack grew very slowly. However, striking exceptions may be found in Tawa, an early variety which grew very slowly, and Saco, a late variety which exhibited fast sprout growth.

A series of field experiments designed for comparison with the present study are in their second year.Records at East Lansing for the past 10 years show a range of 45 days when soil temperature at 6″ depth reached 50° F. at the East Lansing station of the United States Weather Bureau (Figure 4). Problems of diurnal temperature variation arise from studies of this type, and thus far remain unanswered. The evidence obtained indicates that planting potatoes before the advent of soil temperatures in the 48-50° F. range may be unwise, resulting in exposure of seed to conditions unfavorable to growth but favorable to decay.

Summary

Sprout and root growth of potato seed pieces representing ten varieties was studied in the range of 45-60° F. The critical temperature for growth was in the 48-50° range. No consistent association between early maturity and rapid seed-piece germination could be determined.

Excellent sprouting and reasonable root growth did occur at 50°, so that a critical growth temperature for potato seed pieces of 50° F. is proposed.

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EVALUATION OF EFFECTS OF PRACTICES AFFECTING YIELD OF IRISH POTATOES IN ALABAMA[1]

L. M. WARE AND W. A. JOHNSON[2]

INTRODUCTION

Yields of potatoes in Alabama under widely different practices and weather conditions range from 25 to 400 bushels of No. 1 potatoes per acre. Certain weather conditions cannot be controlled by the grower. He can, however, greatly modify the effects of weather by choice of good production practices. Furthermore, he can use practices that offer a possibility of highest yields under favorable conditions, assure good yields under average conditions, and yet protect against failure under unfavorable conditions. Irrigation can offset the damage of deficient rainfall, large seed pieces can reduce the damage of late freezes, and divided fertilizer applications can minimize the damage of excessive rainfall.

PROCEDURES

This study was conducted at the Main Station, Auburn. The purpose was to determine the effects of each of a number of important production practices on the yield of potatoes when used alone and when used in different combinations. Practices studied were fertilizer rates, irrigation, organic materials, size of seed, and spacing of seed. Treatments were arranged in a 3 x 2 x 2 x 2 x 2 factorial design with four replications. Years added a sixth factor. Variance analysis included each of the individual years, the 3-year average, and year interaction.

Studies were conducted in field plots 1/320 acre in size, separated by a 4-inch concrete wall. Fertilizer rates, irrigation, and organic matter additions involved entire plots; seed and spacing treatments involved single rows 15.22 feet in length.

RESULTS

Variations in weather provided unusual conditions for studying both the effects of single practices and combination effects. A severe freeze in 1955 killed plants back to the tubers when the tops were about two-thirds grown; rainfall during the 1956 growing season was one of the lowest on record; and in 1957 the rainfall was quite high.

Yields by treatments and years are given in table 1. Responses to treatments were greatly affected by weather in a given year.

Irrigation

Of the different practices studied, irrigation gave greatest increases in yield (Table 2). The average increase when used with all combinations of practices was 51.1 100-pound bags per acre for the 3 years; the increase in the dry year, 1956, was 103.8 bags. Differences resulting from irrigation

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were highly significant. There was a highly significant interaction between irrigation and years, resulting in a different effect each year from irrigation. Irrigation gave highly significant interaction each year with organic material. This was also true with fertilizer rates each year except 1957, the year of high rainfall. Use of irrigation and organic material jointly gave an increased yield over the 3 years of 38.7 bags per acre above the increases from the two practices used separately. The increases from use of these two practices jointly over increases from the two practices used separately was 48.2 bags for 1956, the dry year, and 48.5 bags for 1955, the year of the killing frost, but only 19.4 bags for 1957, the year of high rainfall. Irrigation applied equaled 1 inch per week when rainfall failed to provide it.

In the dry year, 1956, significant or highly significant interaction occurred between irrigation and spacing and between irrigation and size of seed; there was also interaction among irrigation, spacing, and fertilizer rate in 1955. Over the 3-year period, yields were increased 12.1 bags per acre more by joint use of irrigation and closer spacing than by the two practices used separately. In 1956, the interaction effects resulted in an increase of 16.0 bags per acre for joint use of irrigation and closer spacing, and of 19 bags for irrigation and larger seed. Interaction was not significant between irrigation and these two factors in 1957, the year of high rainfall.

The great value of irrigation in its effect on other practices was shown in 1956 when there was no significant difference in yield resulting from use of different rates of fertilizer, size of seed, spacing of seed, or from use of organic materials when irrigation was not used (Table 1). However, where irrigation was used with the other practices also used, yields were increased 62.4 bags per acre from closer spacing, 52 bags from larger size of seed pieces, 101.9 bags from increased fertilizers, and 90.0 bags from organic materials.

Organic Materials

The addition of organic materials as a single practice gave third highest increases in yield (Table 3). Increases were highly significant each of the 3 years and over the 3-year period; differences were also highly significant from year to year. Increases were 30.9 bags per acre over the 3-year period, 37.7 bags per acre in 1955, 31.2 bags in 1956, and 23.8 bags in 1957.

Interaction was highly significant between organic materials and irrigation each year, all years, and from year to year. It was also significant between organic materials and size of seed in 1955, the year plants were killed, in 1957, the year of high rainfall, and over the 3-year period; none of these interactions was significant during the year of low rainfall. Interactions between organic materials and spacing were highly significant the year tops were killed and over the 3-year period. Interaction between organic materials and irrigation over the 3-year period accounted for 38.7 bags per acre, 7.8 bags more than from organic material alone. This shows the high value of irrigation where organic materials are added or of organic materials where irrigation is added.

Only in 1955, the year tops were killed, did the joint use of organic

TABLE 1.—*Yields of No. 1 potatoes from irrigation and organic materials and from different fertilizer rates, size of seed, and spacing of seed.*

Fertilizer[1]	Organic Materials[2]	Irrigation[3]	Yield in 100-pound Bags															
			¾-Ounce Pieces		1½-Ounce Pieces		¾-Ounce Pieces		1½-Ounce Pieces		¾-Ounce Pieces		1½-Ounce Pieces		¾-Ounce Pieces		1½-Ounce Pieces	
			24″	12″	24″	12″	24″	12″	24″	12″	24″	12″	24″	12″	24″	12″	24″	12″
			1955				1956				1957				3-Year Average			
800	0	0	9.3	9.1	12.9	27.0	4.5	2.6	2.7	1.3	12.2	24.6	20.4	17.3	8.7	12.1	12.0	15.2
1,600	0	0	27.8	30.2	39.2	47.6	5.1	2.4	8.7	6.0	20.6	22.3	24.1	34.4	17.8	18.3	24.0	29.4
2,400	0	0	34.0	20.6	50.3	87.6	9.0	10.9	8.5	3.3	28.9	42.5	40.1	47.6	24.0	24.7	32.9	46.2
800	+	0	16.8	36.5	28.3	44.9	6.3	11.0	15.6	11.5	22.8	28.8	23.2	47.0	15.3	25.4	22.4	34.5
1,600	+	0	27.4	22.5	40.7	97.3	16.3	9.6	12.4	7.0	40.8	38.5	45.4	60.8	28.2	23.6	32.9	55.0
2,400	+	0	35.7	29.6	56.8	121.0	18.7	16.5	12.2	12.9	33.2	44.8	55.8	61.8	29.2	30.3	41.6	65.2
800	0	+	9.2	18.3	48.1	54.8	53.6	60.5	62.1	44.5	5.3	13.2	10.8	4.9	22.7	30.7	40.3	34.7
1,600	0	+	27.0	36.6	74.2	64.5	53.8	99.2	106.5	105.3	16.0	31.9	18.3	26.2	32.3	55.9	66.3	65.4
2,400	0	+	39.6	58.6	50.2	112.3	94.6	112.9	105.7	122.5	36.1	51.2	41.9	67.6	56.8	74.2	65.9	100.8
800	+	+	46.7	53.4	80.4	93.1	106.8	107.6	114.2	110.6	33.3	44.0	42.9	55.9	62.3	68.3	79.1	86.5
1,600	+	+	55.9	75.9	90.6	184.2	122.1	135.9	162.7	164.4	43.7	55.6	63.2	86.9	73.9	89.1	105.5	145.1
2,400	+	+	114.3	150.0	154.6	237.7	136.8	160.5	150.1	212.5	51.7	75.5	64.4	107.8	100.9	128.7	123.0	186.0

[1]Fertilizer was a 6-10-7 grade applied as a 4-10-7 at planting time, and about 3 weeks later, and the balance applied as ammonium nitrate to supply 2 per cent nitrogen.
[2]Organic materials consisted of 2 tons dry lespedeza in winter, 6 tons green crotalaria in summer.
[3]Irrigation applied as 1 inch per week when rainfall failed to provide this amount.

materials and increased fertilizer rate give a greater increase in yield than the two practices used separately.

Fertilizers

Of the single treatments, increased fertilizer rates gave the second highest yield increase. Over the 3-year period increasing the fertilizer rate of a 6-10-7 from 800 to 2,400 pounds per acre gave an increase of 35.0 bags; of the total increase, 18.3 bags came from increasing the rate from 800 to 1,600 pounds per acre and 16.7 bags from increasing the rate from 1,600 to 2,400 pounds per acre.

Over the 3-year period increased fertilizer rates gave a significantly greater increase in yield when used jointly with a larger seed and a closer spacing than when used with smaller seed and wider spacing.

Size and Spacing of Seed Pieces

These two treatments gave consistent although lower increases in yield when used alone than the other treatments. The 3-year average increase for the 12-inch spacing over the 24-inch spacing was 13.6 bags per acre and for the 1½-ounce piece over the ¾-ounce piece the increase was 19.0 bags (Table 2).

Although the average increases in yield from larger seed pieces and closer spacing were not so high when used in all combinations, they were quite substantial in combinations with most intensive treatments. Over the

TABLE 2.—*Differences due to treatments and levels of significance.*

Source of Differences[1]	Differences in 100-pound Bags Per Acre and Significance Level								
	1955		1956		1957		3-yr. Average		Year Interaction Significance
	Amount	Significance	Amount	Significance	Amount	Significance	Amount	Significance	
Irrigation (I)	40.7	.025	103.8	.005	8.8	.01	51.1	.005	.005
Fertilizer (F)[1]	47.8	.005	29.1	.005	27.8	.005	35.0	.005	.005
Organic Materials (O)	37.7	.005	31.2	.005	23.8	.005	30.9	.005	.005
Spacing of Seed (Sp.)	22.6	.005	5.9	.05	12.4	.005	13.6	.005	.005
Size of Seed (S)	38.0	.005	8.5	.05	10.5	.005	19.0	.005	.005
Year (Y)	....		....		....		....		.005
I x F	32.9	.005	49.9	.005	16.0	.1	32.8	.005	.005
I x O	48.5	.005	48.2	.005	19.4	.005	38.7	.005	.005
I x Sp	12.8	.1	16.0	.01	7.6	.1	12.1	.005	.3
I x S	17.1	.1	19.0	.025	1.4	.3	12.4	.01	.1
F x O	29.1	.005	0.1	.3	-6.3	.1	7.7	.1	.005
F x Sp	24.5	.05	16.6	.1	10.0	.1	17.0	.005	.3
F x S	24.6	.10	7.0	.1	10.6	.1	14.2	.025	.3
O x Sp	21.1	.01	2.5	.3	6.5	.1	10.2	.005	.1
O x S	18.0	.05	5.8	.3	12.8	.025	12.3	.01	.3
Sp x S	29.1	.005	-5.1	.3	3.3	.3	9.2	.005	.005
I x F x O	67.6	.005	2.6	.3	7.1	.3	21.1	.005	.005
I x F x Sp	33.3	.1	34.2	.05	20.7	.1	29.4	.005	.3
O x Sp x S	27.2	.1	16.1	.1	14.6	.1	19.3	.005	.3

[1]Difference between 800 and 2400-pound rate of 6-10-7 fertilizer.

TABLE 3.—*Reduction in yield by omission of one, two, or three practices when all other practices are used.*[1]

Practice Omitted	Loss in 100-pound Bags by Omission of Practice			
	1955	1956	1957	1955-57
None Omitted	237.7	212.5	107.8	186.0
Irrigation	116.7	199.6	46.0	120.8
Organic materials	125.4	90.0	40.2	85.2
Fertilizer rate[2]	144.6	101.9	51.9	99.5
Spacing from 12" to 24"	83.1	62.4	43.4	63.0
Size seed from 1½ to ¾ oz.	87.7	52.0	32.3	57.3
Irrigation and organic materials	150.1	209.2	60.2	139.8
Irrigation and fertilizer [2]	192.8	201.0	60.8	151.5
Irrigation and spacing	180.9	200.3	52.0	144.4
Irrigation and size of seed	208.1	196.0	63.0	155.7
Fertilizer and organic materials	182.9	168.0	102.9	151.3
Fertilizer and spacing	157.3	98.3	64.9	106.9
Fertilizer and size	184.3	104.9	63.8	117.7
Organic and spacing	187.5	106.8	65.9	120.1
Organic and size	179.1	99.6	56.6	111.8
Spacing and size	123.4	75.7	56.1	85.1
Irrigation, organic, and fertilizer	210.7	211.2	90.5	170.8
Irrigation, organic, and spacing of seed	187.4	204.0	67.6	153.1
Irrigation, organic, and size of seed	217.1	201.6	65.3	161.3
Fertilizer, organic, and spacing of seed	189.6	150.4	97.0	145.7
Fertilizer, organic, and size of seed	219.4	152.0	94.6	155.3
Organic, spacing, and size of seed	198.1	117.9	71.7	129.2

[1]All practices = irrigation, 2,400 pounds per acre fertilizer, organic materials, 12" spacing, and 1½-ounce seed.
[2]For reduction from 2,400 pounds to 800 pounds per acre for fertilizer.

3-year period, the average increase in yield from closer spacing, when the larger size seed, the highest fertilizer rate, organic materials, and irrigation were used, was 63.0 bags per acre. The 3-year average increase from the larger seed was 57.3 bushels per acre (Table 3).

Accumulated Effects of Different Treatments

The effect of a single treatment was not so large when taken alone. When, however, treatments were added successively, beginning with the least intensive combination of treatments and going to the most intensive combination, increases including effects of interaction were much more pronounced.

There are many different ways by which one might successively proceed from the least intensive combination of practices to the most intensive combination.

One illustration will suffice. The average 3-year yield of potatoes, when the smallest seed, the widest spacing, the lowest fertilizer rate, no organic material, and no irrigation were used, was 8.7 bags per acre (Table 1). Reducing spacing of seed from 24 to 12 inches increased yields from 8.7 bags per acre to 12.1 bags; increasing the size of seed from ¾ to 1½ ounces increased yields to 15.2 bags; adding organic materials increased yields to 34.5 bags; increasing the fertilizer rate from 800 to 1,600 pounds per acre increased yields from 34.5 to 55.0 bags, and from 1,600 pounds to 2,400 pounds increased yields to 65.2 bags; irrigation increased yields to 186.0 bags per acre.

Yields from the most intensive combination were 237.7 bags in 1955, even after tops had been killed, and 212.5 bags in 1956 when extremely dry; in 1957, with excessive rainfall, yields were only 107.8 bags from the best practices.

Importance of Each Practice When All Other Practices Used

The importance of each practice is shown by the loss in yield when one is omitted with all other practices used (Table 3). With all other treatments used, the average 3-year yield was reduced 120.8 bags per acre by omitting irrigation, 99.5 by reducing the fertilizer rate from 2.400 to 800 pounds per acre; 85.2 bags by omitting organic materials, 63.0 bags by increasing the spacing between seed from 12 to 24 inches, and 57.3 bags by reducing size of seed from 1½- to ¾-ounce seed.

General Conclusion

There are a number of general conclusions of a practical nature that might be made from these studies:

1. Each of the good practices, that is, the highest rate of fertilizer, the closer spacing, a larger size seed, and use of irrigation and organic materials, gave significant increases over the 3-year period as well as for each of the separate years.

2. Each good practice not only increased yields but increased the value of other good practices. Organic materials over the 3-year period increased yields 30.9 bags per acre. Irrigation increased yields 51.1 bags. Organic materials and irrigation, when used jointly, increased the yield 112.8 bags, or 38.7 bags more than both of the practices used separately.

3. The omission of any good practice when all other good practices are used may easily jeopardize the effectiveness of all of the other good practices. In 1956, a year of extremely low rainfall, the yield was 212.5 bags per acre where all good practices were used. When irrigation was omitted, only 12.9 bags per acre were produced even though 2,400 pounds of fertilizer, organic materials, 12-inch spacing, and 1½- ounce seed were used. In 1955, when tops were killed by a freeze, yields were 237.7 bags of No. 1 potatoes with all good practices used; where organic material was omitted, it was only 112.3 bushels or where irrigation was omitted, it was only 121 bags.

NEWS AND REVIEWS

THE 43rd ANNUAL MEETING

THE POTATO ASSOCIATION OF AMERICA

UNIVERSITY OF NEW BRUNSWICK
FREDERICTON, N. B., CANADA

AUGUST 12 - 16, 1959

General Information

TRANSPORTATION. The city of Fredericton is serviced by Trans Canada Airlines, Canadian Pacific and Canadian National Railways and is located on the Trans Canada Highway. If you plan to travel by plane, when you make your plane reservation tell your ticket agent that you are attending these meetings. On arrival in Fredericton if you cannot locate the University contact the Tourist Information Bureau or phone 5-3519.

TWO TOURS will be conducted during the meetings. On August 12 there will be a tour up the Saint John River Valley into the potato production area with stops at several points of interest. On August 16 a tour will be made to the Canada Department of Agriculture Potato Breeding Sub-Station at Alma, in the centre of Fundy National Park. For those wishing to stay there longer excellent facilities for camping, golfing, lawn bowling, tennis, and salt water swimming are available. Arrangements have been made with the Maine Agricultural Experiment Station and the U.S.D.A. to welcome visitors on Monday, August 17 at Aroostook Farm, Presque Isle, Maine. Transportation for this *Post Conference Tour* from Fredericton to Presque Isle and return will be available for those requesting it. *Please indicate on the reservation form if you plan to participate in any of these tours,* so that adequate transport will be available. The August 12 and August 16 tours leave Fredericton at 8 a.m., the chartered buses departing from the Student Centre at the University. The transportation facilities and meals en route will probably be free of charge but it may be necessary to charge a moderate fee for transportation. *Those taking the August 12 tour should arrive in Fredericton August 11.*

RESIDENCE ACCOMMODATIONS at the University will be available for single persons, couples, and families. Rates at the University per person for Meals and Room are: August 11-17, $27.15; August 12-17, $23.80; August 12-16, $20.45; August 11-16, $23.80. Charges for periods stated include evening meal on day of arrival and breakfast on day of departure and all other meals except when on tour. Rates for children 12 years and under one-half price. Towels are supplied.

REGISTRATION AND HOUSING APPLICATION

Name MR. / MRS. / MISS ..... (Surname) (First) (Middle)

Title .....

Institution .....

Address .....

Expected time of arrival at Fredericton

..... Date and Hour

☐ By plane
☐ By train
☐ By car

I shall be accompanied by

Wife: ☐ who will ☐, will not ☐ participate in the ladies program.

Wife's name .....

Children: ☐ who will ☐, will not ☐, participate in program of recreation (list children's name, age and sex).

Name Age Sex

.....

.....

.....

.....

Expected time of departure from Fredericton:

..... Date and Hour

Please make reservations for the above in a University Residence ☐ I would prefer housing in a hotel ☐, motel ☐, tourist camp ☐, camp site ☐.

I will not require housing ☐.
I wish to share a room with .....

Remarks: .....

I plan to take the following field trips:
☐ August 12 — Saint John River Tour. I will be accompanied by ..... members of my family.
☐ August 16 — Alma Potato Sub-Station Tour. I will be accompanied by ..... members of my family.
☐ August 17 — Aroostook Farm, Presque Isle Tour. I will ☐, will not ☐ require transportation.

Please print or type the above information and mail to:

Mrs. M. E. MacGillivray,
C.D.A. Research Station,
P. O. Box 280,
Fredericton, N. B., Canada.

Date ..... Date Received .....

RESERVATIONS CANNOT BE GUARANTEED AFTER JULY 25.

OTHER ACCOMMODATIONS will be available in hotels, motels and tourist camps within the city. Rates per day are as follows:

	Single	Double	Twin Beds
Hotel	$5.00-$8.50	$9.00-$10.00	$10.00-$12.00
Motel	$6.00	$9.00	$10.50
Tourist Camp		$5.00 ($8.00 for 4)	$ 6.00

Camping sites available at no cost.

A LADIES PROGRAMME is being planned and arrangements have been made with the City of Fredericton Recreation Department for supervised recreation for children of all ages on August 13-15 inclusive. Please indicate on the reservation form if your children wish to participate in the recreation program.

RESERVATIONS for all housing should be returned as soon as possible on the Registration and Housing Application form. Do not send money with the *pre-registration*. Those wishing to share a room with a particular person should so indicate on the reservation form.

ACKNOWLEDGMENT will be made of advanced registration received prior to July 25. Each registrant will be forwarded a kit containing road maps and other travel information. *Please register early.*

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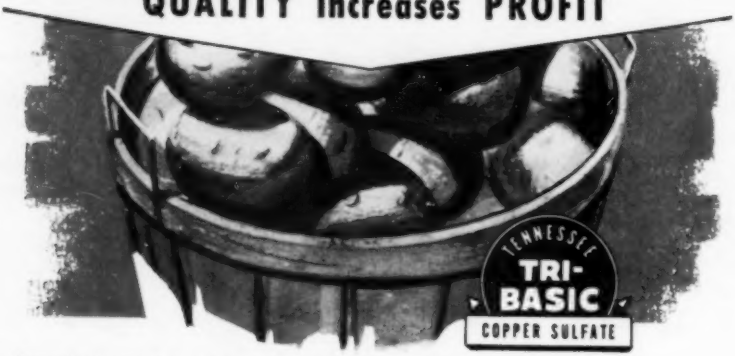

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about controlling blight with

DITHANE® M-22*

"... 30 barrels more per acre."

We tried DITHANE M-22 on about 10 acres of potatoes during 1958 with very satisfying results. During August, about 9 inches of rain fell, and late blight became a serious threat to Aroostook County potato crop. We feel that DITHANE M-22 passed a severe test by giving us better blight control than we had with the nabam fungicide used on the balance of the crop. In addition to the excellent disease control, we had an increase in yield amounting to 30 barrels per acre.

Alfred J. Lausier, KVL FARMS, PRESQUE ISLE, MAINE

"... prefer working with DITHANE M-22."

DITHANE M-22 helped us grow a good clean crop of potatoes last season. Weather conditions during 1958 were very favorable for blight and it was present in the county, but DITHANE M-22 kept our vines clean until harvest. We would also prefer working with DITHANE M-22 to other materials. It is convenient to handle and mixes readily.

J. A. Jones & Son, R.D. #1, BATH, PA.

The reports are the same from all over the country—outstanding potato blight control... better yields ... ease of handling and mixing ... and definite plans to use DITHANE M-22 on a larger scale this season. If you haven't yet discovered the proved advantages of this improved maneb fungicide, check with your Rohm & Haas fieldman or your pesticide dealer before another day goes by. You'll like the results.

"... exceptional control of late blight."

I used DITHANE M-22 on my entire crop of certified seed potatoes during the 1958 season and I feel that the performance of the product was outstanding. During the month of August, we had an excessive amount of rain in Aroostook County and late blight rapidly developed in the area. Despite these severe disease conditions, DITHANE M-22 prevented any late blight development in my crop. Under the circumstances, I feel that DITHANE M-22 gave me exceptional control of late blight.

Athell Banks, MARS HILL, MAINE

"... plan to continue using DITHANE M-22."

Since I grow, buy, and sell potatoes and also sell pesticides, I am in a good position to judge fungicides. My opinion is that DITHANE M-22 does an outstanding job of controlling blight on potatoes. I plan to continue using DITHANE M-22 and will recommend it to all my potato-growing customers.

Jack C. Nichols, MARKY'S WHOLESALE POTATOES, INC., ELBA, N.Y.

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